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REPRODUCTION AND SEASONAL ABUNDANCE OF THE RICEFIELD RAT (*RATTUS RATTUS MINDANENSIS* MEARNS) AT SINILOAN, LAGUNA

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SUBMITTED TO THE GRADUATE FACULTY OF THE COLLEGE OF AGRICULTURE UNIVERSITY OF THE PHILIPPINES IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

MASTER OF SCIENCE
(Applied Zoology)

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The thesis attached hereto, entitled "Reproduction and Seasonal Abundance of the Ricefield Rat (Rattus rattus mindanensis Mearns) at Siniloan, Laguna", prepared and submitted by Bernardo E. Marges, in partial fulfillment of the requirements for the degree of Master of Science in Applied Zoology is hereby accepted.

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BERNARDO E. MARGES

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ABSTRACT

Marges, Bernardo Espiritu, University of the Philippines, November, 1972, Reproduction and Seasonal Abundance of the Ricefield Rat (Rattus rattus mindanensis Mearns) at Siniloan, Laguna. Major Professor: Pablo J. Alfonso

The reproductive patterns and seasonal abundance of the common ricefield rat were studied in an irrigated ricefield in Siniloan, Laguna from August, 1971 through July, 1972. The study area was planted to two crops of rice every year. Of the two rat species found, the ricefield rat dominated the entire riceland community comprising more than 99 percent of the total collection.

Two age classes were recognized: juveniles and adults. Adults were further subdivided into breeding and non-breeding. The vaginal orifice became perforate at 54.45 grams among females, while the testes descended to the scrotum at 134.93 grams among males. For both sexes the skull ossified at 90.79 grams. The length of the testes was significantly correlated with the body weight. Active sperms were present in the cauda epididymis when the testes reached a length of 22.29 mm. Once sexual maturity was attained males remained fertile throughout the year.

Reproductive pattern was sharply bimodal, corresponding very closely with the crop cycle. Most litters were produced during the reproductive and ripening stages of rice plants, with little or no breeding activity when the fields lie fallow. There was no direct relationship between breeding and seasonal or climatic changes. Mean

litter size was 9.67 but decreased significantly during the beginning and termination of the breeding period. There was no tendency for the number of embryos to increase with body weight. The distribution of embryos between the right and left horns of the uterus was entirely independent, with no marked tendency for all embryos to develop on one side or the other. The annual incidence of pregnancy was 5.67 litters; the number of litters produced during the dry season breeding was more than twice that of the wet season breeding. With few exceptions, the sex ratio approximated equality. Of the exceptions most could be shown due to differential trappability of both sexes at certain stages of the breeding period. Productivity was high, about 44 young being produced per female per year.

Seasonal reproduction resulted in high population density by August, September and October. Sharp decline in density was observed in January, February and March.

INTRODUCTION

Rats have always been a problem in Philippine agriculture. There were early reports of serious rat depredations in the Bicol region and in the Mountain Province (Crucillo, Otanes and Morales, 1954) but these lacked the details that would provide better meaning and importance to such apparently localized and short-term irruptions. Similar severe infestations but notably of longer durations were known to exist in large sugar estates in Mindoro and Negros islands (Quizon, personal communication), but loss of records during the last war denies to present workers information on rat species and their patterns of growth and abundance in cropland conditions. The near simultaneous and widespread rodent outbreaks in Cotabato (Sarmiento, 1953), Davao and adjacent provinces in Mindanao in 1952-53 provided the first Philippine experience which considers rats as an agricultural pest of national economic importance (Crucillo, et al., 1954 and Villadolid, 1954). Since then rat outbreaks, occurring at times to the proportion of a plague, have severely affected rice and corn production before harvest, while also affecting the potentials of sugar and coconut exports in all principal islands and regions of the country.

The Philippine ricefield rat, Rattus rattus mindanensis Mearns, is the most prevalent rodent form affecting local agriculture (Barbehenn, Sumangil and Libay, in preparation). It is chiefly responsible for most of the damage in cereal crops where the value of crop losses to rice and corn alone was estimated to reach 160 million pesos annually (Sumangil, et al., 1970).

In spite of its widespread distribution, the ricefield rat has been the subject of relatively few detailed studies on reproduction and population dynamics. To obtain reliable records on the breeding of most wild mammals, one must rely mainly on post-mortem examinations of an adequate number of the species collected at intervals over a period of one or more years. These conditions were approached by Rosell (1959) with four consecutive years of study on the breeding activity of Rattus argentiventer in ricefields and wastelands of Cotabato and by Sumangil, Segui and Macanas (1963) on three intervening periods in the succeeding years. Sumangil and Aquino (1958) further reported some breeding data on R. r mindanensis and R. argentiventer collected in croplands and forest clearings in Mamburao, Mindoro Occidental. Supplementary data on the ontogeny and laboratory breeding were also obtained by Rosell (1959) on R. argentiventer and Medina, et al. (1972) on R. r. mindanensis.

More details on the reproductivity and breeding activity of R. r. mindanensis on the basis of geographic location were reported from International Rice Research Institute, College, Laguna (Uhler, 1967), some southern localities of Laguna (Sanchez et al, 1971), and Muñoz, Nueva Ecija (Alfonso and Castillo, 1970). It is apparent from these reports that where rainfed areas are involved the main breeding period coincides with the rainy season and period of rice cultivation (June to December), with much reduced breeding activity during the dry or summer months (January to May). This breeding periodicity results in rapid seasonal build-up of population and may also partly explain the results obtained by LaVoie et al. (1970) who found that tiller destruction by rats during the vegetative growth period of rice was light but increased

appreciably during the reproductive and ripening stages of development. Sumangil (1971) observed that the presence of choice food and superior cover offered by booting rice attracts rat movement from surrounding wastelands into rice fields. Thus, irruptive populations are commonly associated to serious crop damage before harvest.

The basic breeding cycle of animals may be affected either favorably or adversely by various environmental factors. Through his agricultural practices, man has altered his environment to favor the existence of many species, including field rats. Extensive use of irrigation in Laguna province during the dry season has converted wastelands and fallowed areas into productive rice fields. Hence, many irrigated farms are planted to rice during the dry season. This provides rats with adequate supply of food and cover even during the dry months of the year. Uhler (1967) observed at IRRI, where irrigation is continuous and rice is grown throughout the year, that R. r. mindanensis exhibits a year-round breeding season. The effects of environmental factors, particularly climate and food requirements, on the breeding cycle of rats is emphasized by Sumangil (1965) who states that "where food is always plentiful and climate more or less even throughout the year, rats breed and reproduce anytime or month of the year".

Knowledge on the reproductive activity of the ricefield rat, particularly breeding season, is needed before any realistic reduction program can be evolved. By understanding population changes in relation to season and habitat, reduction measures may be instituted at a critical stage before a population increase.

The present study was undertaken from August, 1971 through July, 1972 to collect information on the reproductive pattern of rats in an irrigated ricefield and to determine population changes in relation to seasonal and habitat changes. In a broader context, the study offered an opportunity to examine in detail the mechanisms of population regulation of a single mammalian species in a typical riceland ecosystem.

TAXONOMY AND DISTRIBUTION

Rattus rattus mindanensis is the most widely distributed Philippine species and is chiefly responsible for the destruction of rice and other crops in Luzon and Visayas. In Siniloan, Laguna it represented more than 99 percent of the total rat collection; all others are Rattus exulans. Although originally described by Mearns as a distinct species (Taylor, 1934), the ricefield rat is now designated Rattus rattus mindanensis (Barbehenn et al., 1972; and Johnson, 1962). It is medium-sized rat, with adults averaging about 180 grams. The tail is usually longer than the head and body and is uniformly black or dark brown; scalation is variable. The hind foot averages 40 mm in length, but the range of 36 to 45 overlaps that of many species of rats. Plantar pads are well developed. Ears, measured from the notch, averaged 21 mm (range 19 to 23). Pelage color is quite variable; ranging from grayish brown to reddish chestnut dorsally and usually blending gradually into a paler venter, which is even more variable - from creamy white to dirty grey, often with a wash of buff of variable intensity (Barbehenn et al. 1972). The ricefield rat typically has two pairs of pectoral and three pairs of inguinal mammae, with the anterior pair actually being abdominal

and more distinct from the middle pair than the posterior pair. To the non-taxonomist the various sub-species are very similar and where ranges in measurement overlap it is extremely difficult to separate them.

In the whole islands of Mindanao and some parts of Mindoro where Rattus argentiventer dominates rice field communities, it becomes more commensal in its distribution (Barbehenn et al. 1972). According to Sumangil (1968) this species has a pasticular liking for human dwellings and generally destroys backyard fruit crops, particularly coconuts and banana plantations, as well as stored rice and corn. In Cotabato, more than 90 percent of those caught near and inside houses belong to this species. Barbehenn et al. (1972) considered R. r. mindanensis to be an endemic sub-species in the Philippines since it is presumed to occur on virtually every island. The animals are found from grassland at sea level to over 6,000 feet in Luzon and Mindoro, although they are less common in higher altitudes.

DESCRIPTION OF THE STUDY AREAS

The study area was located in Siniloan, Laguna, about two kilometers from Laguna de Bay shoreline, at an approximate elevation of slightly above sea level. The topography is relatively flat with slight decline to the east toward the base of Sierra Madre mountain. An area of approximately one square kilometer within and around the periphery of Baybay National Agricultural and Vocational School was used as the primary collection site (Figure 1). It is dissected by a number of small and shallow creeks and larger tributaries that result in overflow during the rainy season with any marked rise in lake water.

Fig. 1. Portion of the study area showing conditions of the rice paddies after harvest.

The climate is characteristic of the lowland areas of Laguna province (Table 1). The average annual precipitation for Siniloan over a two-year period was 199.04 mm. Average monthly precipitation did not seem to vary widely from year to year; the average for 1970 and 1971 wa 188.25 and 209.82 mm, respectively. The bulk of the rainfall usually occurred from July through December. In 1971 much of the rainfall occurred during the period from October to December, while in 1972 the effects of monsoon rain caused a peak rainfall in July with 767.0 mm of rain. This abnormally high precipitation inundated and submerged the entire study area a week after the last specimen collection was made. The monthly mean temperature for Siniloan did not vary widely. The monthly mean temperature ranged from 24.69 to 28.32°C, with an average of 26.78°C during the whole period of study.

Although there are two cropping season annually, rice production in Siniloan is entirely dependent on the depth of water in the paddy fields. Unlike in many other Laguna towns, the first or regular rice crop is transplanted in January, and all the paddy fields are planted in late February. Harvest occurs mostly in May and June. The second crop or "palagad" rice is transplanted in July and August and harvested in November and December. Because most of the areas are water-logged during the rainy season, only about half of the total hectarage is planted to rice. Hence, the amount of cereal food available to the rats during the rainy season is comparatively less than during the dry season.

Weeds are a constant problem on the paddy fields. The unplanted areas remain largely covered with succulent grasses composed mostly of

Table 1. Monthly mean rainfall and average temperature in Sinilcan.

Month	1970		1971		1972
	Rainfall (mm)	Air temp. (°C)	Rainfall (mm)	Air temp. (°C)	Rainfall (mm)
January	40.9	25.55	12.5	24.69	47.0
February	16.8	25.53	25.6	25.41	2.5
March	20.1	27.18	82.7	25.63	74.9
April	20.3	28.28	18.3	27.26	16.2
May	19.8	29.26	229.8	28.32	158.2
June	177.5	28.58	251.1	27.78	428.0
July	149.6	27.73	314.6	27.47	767.0
August	182.4	27.47	165.8	27.74	-
September	359.2	27.00	208.5	27.96	-
October	516.6	27.25	418.5	26.88	-
November	577.0	26.82	340.9	26.27	-
December	178.8	26.54	449.6	25.97	-
Mean	188.25	27.27	209.82	26.78	213.40

"bayakibok" (Echinocloa crusgalli) and large stands of "tikiw" (Scirpus grossus) are equally conspicuous. River banks and marginal areas are covered with thick stands of "talahib" (Saccharum spontaneum); while paddy dikes and irrigation canals were dominated by thick matting of para-grass (Brachiaria mutica). The presence of succulent weeds and ratooning rice plants after harvest affords the rats ample cover and food throughout the year.

MATERIALS AND METHODS

A. Collection of Rats

Post-mortem examination of 932 rats collected at two-week intervals from August, 1971 through July, 1972 in irrigated rice fields formed the basis of this study. Animals were generally collected by Victor snap traps. Supplemental collections were made by hand capture (blanketing) of animals in grassy areas. Snap traps were placed along paddy dikes in two or three transects each composed of 50 or more traps. Distance between traps was about 5 meters and the space between transects varied according to the distance between paddy dikes or about 50 to 100 meters. The trap lines were usually operated for 2 or 3 consecutive nights. Baits consisted of fresh coconuts or sliced sweet potatoes. The trapping lines were moved into a different collection site for each trapping period, and were located systematically to enable sampling the entire study area. The number average of specimens examined per month was 77.66 with a range from 14 to 194 rats. Generally, the monthly samples consisted of more than fifty animals.

B. Autopsy

Necropsy was conducted in the field as soon as specimens were collected. All animals were identified, sexed and weighed separately. In the case of gravid females the difference in scale, after removing the weight of the embryos and enlarge uterus, was taken as the weight of the parent. In addition, standard physical measurements (total length, tail length, ear length and hind foot) were recorded.

The reproductive condition of the males was determined by examining the position of the testes and recording them as scrotal or abdominal. Testicular length and width was measured in millimeters and the conditions of the cauda epididymis were noted. Rats with enlarged scrotal testes with visible tubules in the cauda epididymis were considered reproductively active.

The condition of the female reproductive organs were determined by making a median incision on the ventral surface of the abdomen and examining the uterus *in situ*. Females were classified as reproductively active if they were pregnant, lactating, or had opened vaginal orifice. The presence of spots or placental scars in the wall of the uterus were recorded. However, no attempt was made to count the uterine scars, because this criterion was not reliable for determining litter size (Davis and Emlen, 1948). A rat was classed as pregnant if the embryos are macroscopically visible, and lactating if milk can be expressed by the fingers from the nipples. For the embryos actual crown-rump length was measured when the specimen was large enough (3 mm or more). The number of embryos contained in the right and left horns of the uterus

were recorded. Dead embryos and those being resorbed (smaller than the majority that development is obviously abnormal) were noted and used to estimate the loss of embryos during pregnancy.

Ossification of the skull was determined qualitatively by resistance to finger pressure (Davis and Hall, 1951).

C. Statistical Analyses

The annual incidence of pregnancy, or the number of litters born to a female was approximated from estimates of prevalence of pregnancy (Emlen and Davis, 1948; Davis and Hall, 1951). Sex ratios were expressed in percent males and were tested for statistical significance by Chi-square analysis. Maturity based on the perforation of the vaginal orifice in females, presence of scrotal testes in males, and ossification of the skull in both sexes were determined by correlation and regression analysis.

In determining reproductive trends, the data were analyzed by months, and also by seasons. Monthly mean litter size was tested for statistical significance by the use of Analysis of Variance and mean differences was determined by Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

A. Criteria of Maturit

Determination of chronological age in feral rats is difficult because growth and development rates may vary in each individual and in different populations. Were it possible to observe individuals over

a period of time, the different ages at which they attained a given level of development could be determined. However, since the animals in the present study were examined at but one stage in their development, only the presence or absence of a given character could be observed. Characters often used for differentiating adults from juveniles are based on the capacity of the animals for breeding. Though animals are adult by chronological criteria, they can play no part in the reproductive phases of the population dynamics until motile sperm are contained in male reproductive tracts or until ovulation has occurred in females (Jackson, 1952).

Use of weight at which 50 percent of the animals possess a given characteristic is preferrable to 100 percent level, since the latter may be unduly affected by a few slowly maturing individuals (Jackson, 1952). These 50 percent points were calculated from the regression of percentages on the body weight.

Table 2 shows the sizes of the ricefield rat at various stages of maturity. The weight at which 50 percent of the females have the vagina perforate was 54.45 grams, although some females may become perforate at weights as low as 40 grams. However, these newly perforate females show no development of reproductive tracts. Perforation is not indicative of sexual maturity in females due to the presence in the population of newly perforate females which lack ovarian development.

In the males rapid increase in weight is not normally accompanied by maturation of the gonads or accessory glands. The testes become scrotal in position at 134.93 grams, while sperms were present in the

Table 2. Size of the ricefield rat at various stages of maturity.

Characters	Weight in grams	
	No. of rats	50 percent point
Vaginal orifice perforate	450	54.45
Skull ossification	927	90.79
Testes scrotal in position	477	134.93
Sperm in cauda epididymis	55	154.47
Placental scars	450	185.55

cauda epididymis at 154.45 grams. The weight at which 50 percent become fertile gives a measure of the average weight of onset of fertility.

Ossification of the skull occurred after the rats attained the weight of 90.79 grams.

The presence of scars in the uterus is a good indication that implantation has occurred. Thus if the animals are grouped by size and classed as parous (individuals with scars or visible embryos) or non-parous (individuals without scars or visible embryos) a measure of the size at first pregnancy can be obtained (Davis and Emlen, 1948). The lowest weight at which first pregnancy occurred was 105 grams which can be taken as a measure of the age of puberty. Of the 107 pregnant females examined, 86.54 percent weighed more than 165 grams.

1. Testis position, size and fertility

Position and size of testes have been used as the most important criteria of breeding in males. Testes in the ricefield rats may occupy either abdominal or scrotal positions. Both testes generally occupy the same position. Descent may occur at an early age, depending upon the season, since scrotal testes were found among males weighing well below 50 grams during the months of April and October. The proportion of males with scrotal testes increases with weight, thus showing some relationships between position of testes and sexual maturity. Recent studies by the Rodent Research Center indicate that rats with active spermatozoa invariably had scrotal testes, although 45 percent of the adult males with no apparent sperm activity (epididymal tubules not visible) had scrotal testes (Swink et al., 1970). Descent of testes is not a very good index of fertility in the ricefield rats.

Table 3 shows that there is a high proportion of males with scrotal testes throughout the year. Considerable reduction in the proportion of males with scrotal testes in June and July was due to the presence of more juveniles in the population. Since this species is capable of producing active spermatozoa throughout the year in both irrigated and rainfed areas (Swink et al., 1970), then the occurrence of seasonal changes in the pregnancy rates cannot be attributed to seasonal changes in the capacity of males to fertilize.

Length of testis was used as an index of testis size. Miller (1946) observed that length and weight of testes among pocket gophers

Table 3. Monthly composition of adult male population of *Rattus rattus mindanensis* with respect to position of testes.

Month	Total males examined	Testis position		Percent scrotal
		Abdominal	Scrotal	
August, 1971	8	1	7	87.50
September	40	12	28	70.00
October	30	8	22	73.33
November	69	15	54	78.26
December	114	28	86	75.44
January, 1972	22	8	14	63.63
February	10	3	7	70.00
March	9	2	7	77.77
April	43	13	30	69.76
May	38	14	24	63.15
June	56	40	16	28.57
July	43	27	16	59.25
Total and average	482	171	311	64.52

are closely correlated ($r = 0.87$) so that length is an adequate estimate of size. Laurie (1946) found among mice that if the tubules in the cauda epididymis are visible to the naked eye, they invariably contained large number of sperms and that the individual would be fecund. In the ricefield rats, the presence of sperm is usually associated with a testes length of between 20 and 32 mm (Figure 2). It was also found that a testes weight of 22 mm or over was almost invariably associated with fecundity, that is, with large number of sperm in the cauda epididymis. Below the length of 20 mm, the cauda epididymis was nearly always without sperms, that is to say, the males are non-fecund.

B. Reproduction

1. Breeding season

The seasonal reproductive pattern of *Rattus rattus mindanensis* in Siniloan, Laguna are summarized in Table 4 and Figure 3. Although the proportion of adult males capable of producing active sperms remained high throughout the year (Swink et al., 1970), reproductive activity of adult females show seasonal trends. Analysis of the monthly prevalence of visible pregnancy and incidence of juveniles in the population indicates that this species features a sharp bimodal breeding curve, peaks occurring from March to April and October to November. This is in general agreement with Uhler (1967) who also observed bimodality in the breeding pattern characteristic of this species at the International Rice Research Institute, College, Laguna.

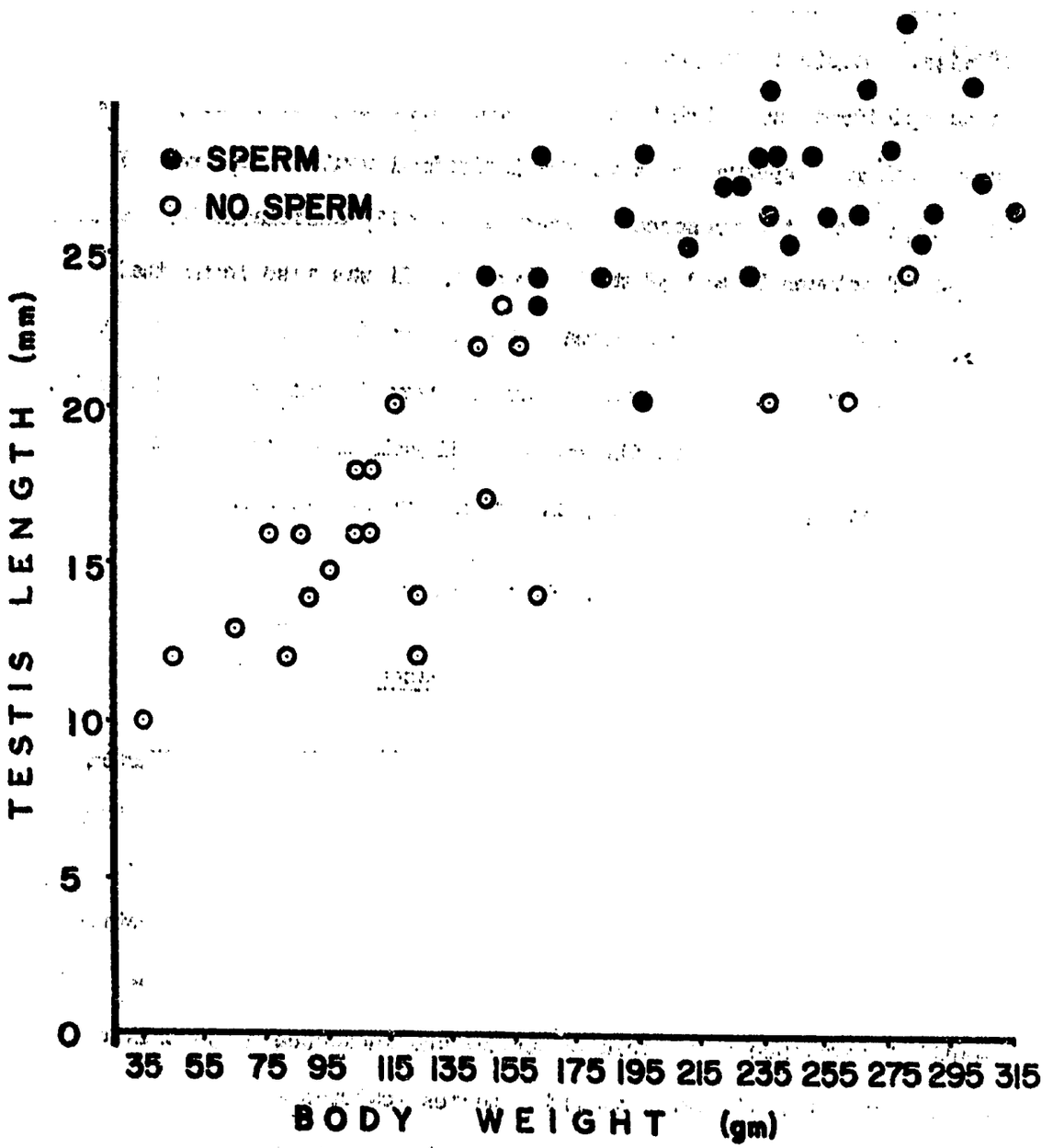

Fig. 2. Scatter diagram of length of testis against weight f rats showing presence or absence of sperm.

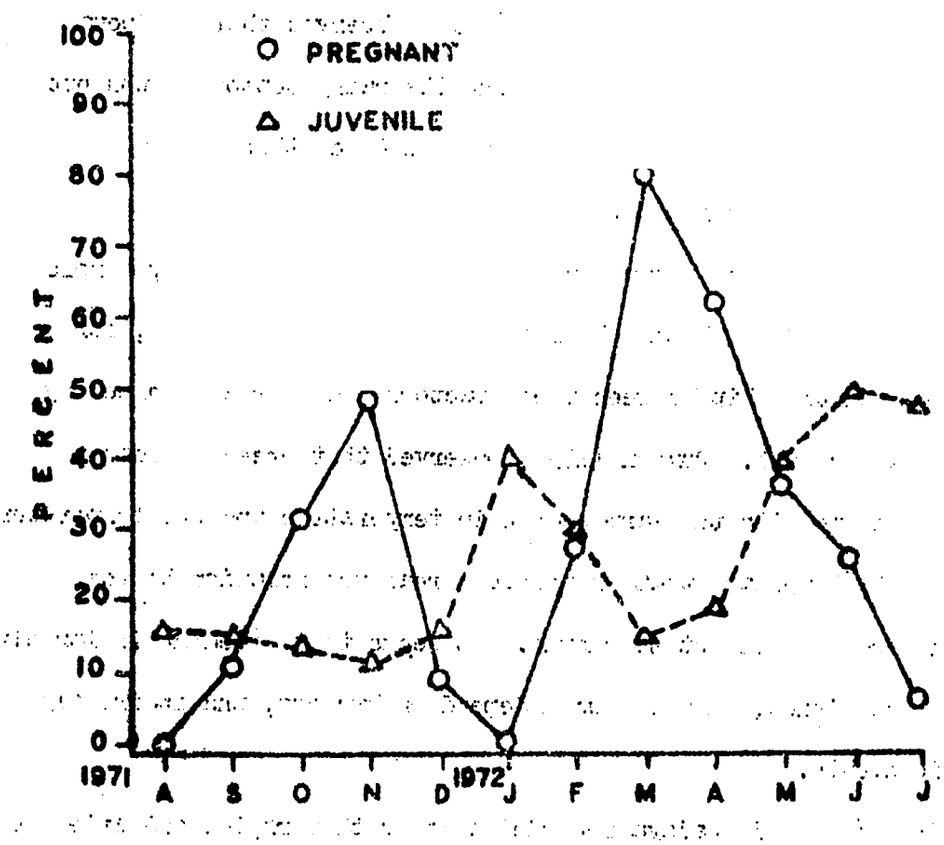

Fig. 3. Graph showing extent of breeding season judged by percent pregnant and immature.

In other parts of the Philippines, a unimodal curve has been found. In Cotabato, the ricefield rat breeds actively during the rainy season (June to December), followed by no breeding activity from January to early part of June (Sumangil et al., 1963; Rosell, 1959; and Sumangil and Rosell, 1959). Sanchez et al (1971) also observed that in Nueva Ecija, this species breeds actively during the rainy season months but ceases completely during March, April, May and June, this period corresponding to the dry season.

Jackson (1952) stated that many environmental factors play a role in the regulation of small mammal breeding. The basis, however, for the apparent relationship between these factors and increased breeding is not well understood. Buxton (1936) observed that breeding season appears to combine with the warm season in temperature and sub-temperature climates. But it appears that in monsoon areas the relation between climate and breeding is not so simple. It seems that breeding is largely a matter of nutrition, that may well depend on harvest, and indirectly on climatic events.

Harrison (1952) in Malaya recorded a bi-monthly rhythm and attempted to relate it to the lunar cycle. No such correlation has been attempted with the present data. Sumangil and Rosell (1959) generally regarded climate as the main factor affecting the rhythm of reproduction of the ricefield rat. They observed significant correlation between reproduction and rainfall. In Malaya, Harrison (1952) has shown that rats appeared to have no breeding season, although breeding activity may show fluctuations related to rainfall.

In this study, correlation of monthly prevalence of pregnancy with rainfall showed a slight negative relationship ($r = 0.35$). When the monthly prevalence of pregnancy was correlated with the number of rainy fays each month, the relationship remained slightly negative ($r = 0.446$), indicating that seasonal changes has very little effect on the reproductive activity of the rats. This tends to show that in effectively irrigated areas where rice can be grown at all months of the year, rats can breed continuously regardless of seasonal fluctuations. As shown in Figure 4, the rainy season breeding seems to be significantly correlated with rainfall ($r = 0.447$), while dry season breeding appears to be negatively correlated with rainfall ($r = -0.30$). This may explain the significant relationship between reproduction and rainfall reported by Sumangil et al (1963) and Sumangil and Rosell (1959). Apparently, their data were gathered from rainfed fields where seasonal cycle and crop cycle correspond more closely than in irrigated areas. In rainfed areas the farmers entirely depends from rain to start land preparation and planting.

Table 4 indicates that active breeding in rats is directly related with the presence of rice in the field. In Siniloan, dry season breeding appears to be of greater intensity and of longer duration than during the rainy season. This may be attributed to the fact that wider area was planted to rice during the dry season. Hence, more food is available to the rats as a source of nutrition to maintain their breeding activity. Breeding may be reduced or terminated when cover and food supply are depleted or when competition for resources, such as food, nest sites, and harborage is high (Sanchez et al., 1971). Sumangil and Rosell (1959) observed that the rate of reproduction of laboratory-reared rats diminishes with the reduction of protein supply.

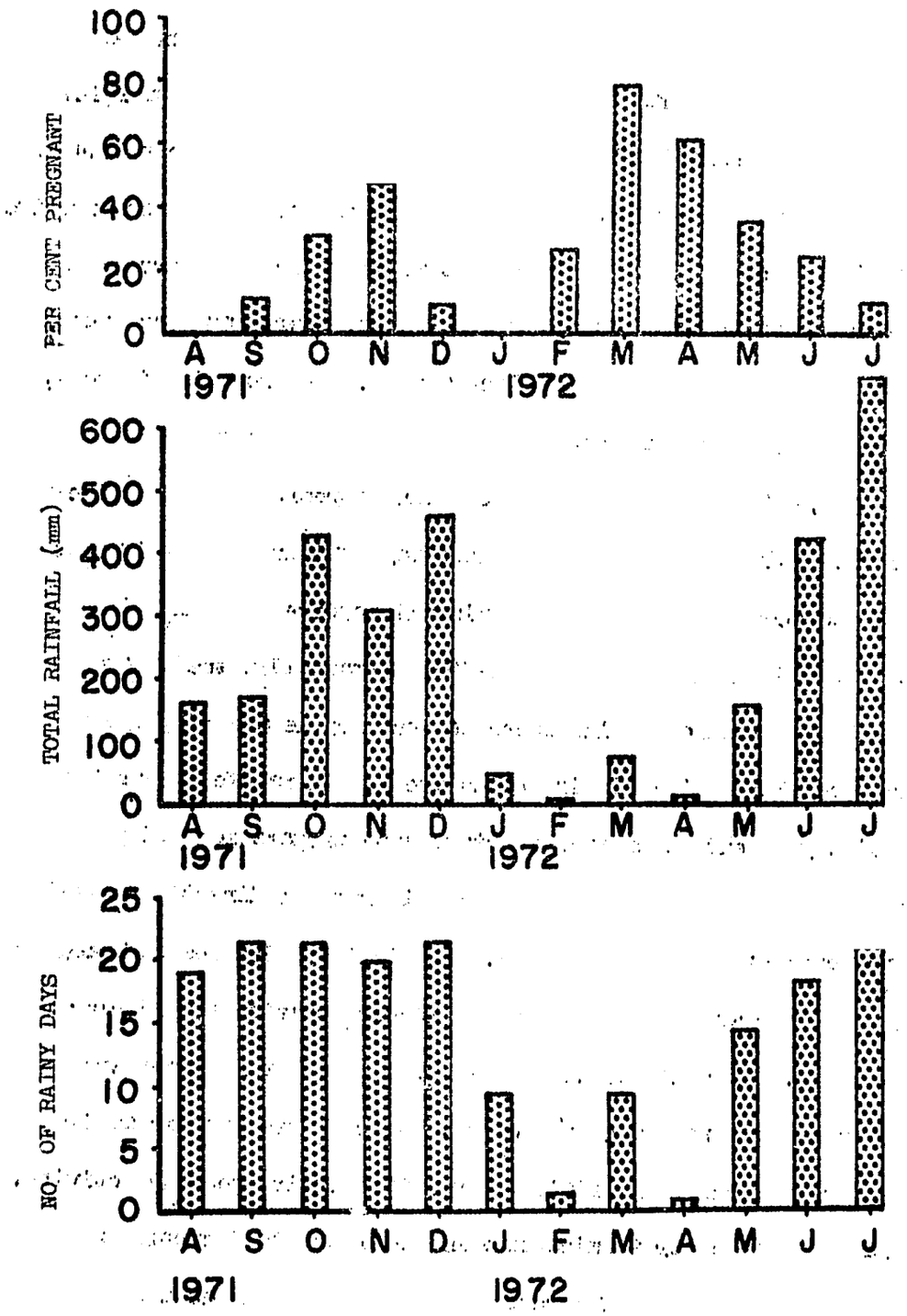

Fig. 4. Monthly changes in the prevalence of pregnancy in relation to total monthly rainfall and number of rainy days per month.

Table 4. Monthly changes in the prevalence of pregnant *Rattus rattus mindanensis* in Siniloan, August, 1971 through July, 1972.

Month	No. of adult females	Number pregnant	Percent pregnant[a]	Embryos per female	Growth stages of rice
August, 1971	14	0	0	0	transplanting
September	38	4	10.52	6.50	tillering
October	21	6	31.57	9.67	booting, heading
November	79	38	48.10	9.68	mature, harvesting
December	80	7	8.75	8.86	post-harvest
January, 1972	23	0	0	0	seedbed, land prep.
February	11	3	27.27	7.0	transplanting
March	5	4	80.00	10.75	tillering
April	32	20	62.50	10.45	booting, heading
May	30	11	36.67	11.18	mature, harvesting
June	47	12	25.53	9.16	post-harvest
July	37	2	5.41	7.50	seedbed, land prep.
Total and averages	417	107	28.02	9.67	

a/ Prevalence of pregnancy based on total number of females with perforated vaginal orifice.

According to Nelson and Evans (1955), thiamine is essential for the normal reproductive performance in the rat. Nelson and Evans (1955) cited Evans and Bishops (1922) who reported the immediate cessation of estrous cycles in rats placed on vitamin B-deficient diets. Ueno (1934) and Coward et al. (1942), as cited by Nelson and Evans (1955), independently mentioned the occurrence of reproductive distrubance in rats deficient in vitamin B or B_1. These results strongly suggest that seasonal fluctuations in the breeding activity is dependent on the quantity of animal and vegetable food available to the rats.

2. Prevalence of pregnancy

Prevalence of pregnancy (per cent pregnant) was based on the number of adult females per month. Annual prevalence was calculated by averaging the estimates from the monthly samples. Table 4 shows that the variability of the breeding intensity was oriented around two peaks of activity. One occurred in November when about 48 percent of the sexually mature females were pregnant, and a second and higher one in March and April when about 65 percent of the mature females are pregnant. High percentage of pregnant females during March may not be reliable since the number of individuals involved was not large. It is possible that non-breeding animals coming from surrounding wastelands were included in the samples during the palagad crop. This may account for the low reproductive rate during the rainy season. This is in agreement with the observation of Sumangil (personal comm.) at Midsayap, Cotabato where he found that one-third of the annual reproduction occurred during the palagad planting.

Although the data from the present study are inadequate to determine actually the factors responsible for initiating active breeding, it is evident that the prevalence of pregnancy increased markedly during the reproductive and ripening phases of the rice growth. A prevalence of 5.26 and 8.75 percent during the months of July and December indicates a sharp decline and termination of the breeding seasons.

3. Incidence of pregnancy

The incidence of pregnancy, or the number of litters born to a female during a known period of time, was calculated from estimates of the prevalence of pregnancy (Emlen and Davis, 1948; Davis and Hall, 1951) by using the formula, $I = \frac{Pt}{d}$, where I is the incidence during a time, P is the prevalence of pregnancy, t is the time of interval of observation in days, and d is the number of days during the gestations period of rats that embryos are visible in the uterus, which is about 18 days.

The annual incidence of pregnancy of Siniloan field rats of 5.68 liters was based on 417 adult females. This is not significantly different from those reported by Sanchez et al (1971) of 5.9 liters for this species in three southern municipalities of Laguna. It is slightly higher (I = 5), though may not be statistically significant, from the observations of Sumangil and Rosell (1959) for this species in Occidental Mindoro and for other species for most other parts of the world (Jackson, 1952).

To compare the incidence between two crop cycles, the data are summarized for seasonal differences as suggested by Davis (1953). The percentage pregnant for all months (or seasons) were summed and then divided by the number of months. The method essentially assumes that an equal number of rats (100 was caught in each month. The incidence of pregnancy was 4.05 litters during the dry season and 1.64 litters for the rainy season. It appears that ricefield rats in Siniloan are able to produce more than twice the number of litters during the regular crop planting than during the palagad or second crop planting. This results in a rapid increase in the population towards the termination of the dry season breeding.

4. Litter size

Estimates of litter size was derived from counts of presumed normal fetuses. Based on fetus counts the mean number of embryos per female is 9.67, with litters ranging from 5 to 17 (Table 5). Counts of very young fetuses may be of less value in determining litter size as some loss of young may occur after this age (Wirtz, 1970). Loss of ova before fertilization or resorption of embryos are among the factors that may reduce litter size in mammals. Resorbing embryos were found in 11 of 107 pregnant females examined. One fetus was affected in more than half of the cases, while 2 were affected in 3 cases. Intrauterine mortality of 2.12 percent is significantly lower than that reported by Sumangil

Table 5. Monthly mean distribution of fetuses in the two horns of the uterus of pregnant rats examined in Siniloan, Laguna, August, 1971 through July, 1972.

Months	No. of pregnant females	Total no. of embryos	Right horn	Left horn	Mean no. of embryos
August, 1971	0	0	0	0	0
September	4	26	12	14	6.50
October	6	58	28	30	9.67
November	38	368	179	189	9.68
December	7	62	31	31	8.86
January, 1972	0	0	0	0	0
February	3	21	11	10	7.0
March	4	43	21	22	10.75
April	20	209	110	99	10.45
May	11	123	67	56	11.18
June	12	110	56	54	9.16
July	2	15	10	5	7.50
Total	107	1035	525	510	9.67

and Rosell (1959) of 9.6 percent. This may be attributed to the difficulty encountered in determining normal from resorbing fetuses during the early stages of pregnancy.

Table 5 shows the distribution of fetuses in the two horns of the uterus. Based on 107 pregnant females dissected from which 1,035 embryos were counted, 525 or 50.72 percent were lodged on the right horn of the uterus, while 510 or 49.28 percent were lodged on the left horn of the uterus. Except for one case where all of the 7 embryos developed on the right side of the uterus, there seems to be no tendency for the embryos to develop on one side of the uterus or the other. It is evident that embryo development among the ricefield rat is entirely random and independent. This is in contrast with the report of Harrison in Malaya (1951) where one side of the uterus was favored for embryo development in Rattus argentiventer.

Table 6 shows the analysis of variance for the number of embryos of all pregnant females. The mean separation are shown in Table 7. The average litter size recorded during the months of February, July, September and December are significantly smaller ($p = 0.05$) than those obtained for the other months. This indicates that litter size produced between crop cycles decreases when food is scarce and competition for other resources is high. There seems to be no correlation between the weight of the parent and the size of litter ($r = 0.2$).

Table 6. Analysis of variance for litter size

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Months	9	120.55	13.19	2.49*
Error	97	521.01	5.37	
Total	106	641.56		

*Significant at 5% level

Table 7. Mean litter size separation of all pregnant rats examined for this study in Siniloan, Laguna.

Sept.	Feb.	July	Dec.	June	Oct.	Nov.	Apr.	Mar.	May
6.50	7.0	7.5	8.86	9.16	9.67	9.68	10.45	10.75	11.18

No significant differences among months connected by line

Separation by Duncan's Multiple Range Test (a = .05)

5. Productivity

Annual productivity estimates are greatly affected by variation in the estimated sex ratio and the proportion of adult females in the population. As shown in Table 8, the embryo productivity was 43.96 per female per year. This value was obtained by multiplying the average number of viable embryos per female and the incidence of pregnancy. Bi rate (birth per rat per year) was calculated by multiplying the annual embryo production by the percentage of adult females in the population and the sex ratio (Davis and Golley, 1963). Table 8 shows that the rate of birth among ricefield rats was 9.31 young per rat. This did not

Table 8. Productivity of *Rattus rattus mindanensis* captured during monthly trapping in Siniloan, Laguna.

Annual prevalence of pregnancy	28.02
Annual incidence of pregnancy	5.68
No. of months without breeding	2.0
Average no. of viable embryos/female[a/]	7.74
Embryos/female/year	43.96
Age ratio (% adult)	73.79
Sex ratio (% male)	51.83
Adult females (% of total)	40.88
Birth rate (birth/rat/year)	9.31

a/ Based upon *in utero* counts and corrected by an estimate of 20% uterine mortality published for closely related species.

differ significantly from the results obtained by Sanchez et al. (1971) for both rainfed and irrigated conditions. In the real population young and even some adult females do not breed, hence, the rate is even lower. These results show that under the conditions obtaining in the rice fields, the rats have a high potential rate of increase.

6. Juvenile incidence

Supplementary and confirmatory evidence on breeding may be furnished from other sources. The age composition, particularly the incidence of juveniles, may provide valuable clues. A continuous stream of juveniles contributes to the monthly samples, but their relative frequencies that the gestation period of rats ranges from 21 to 22 days. Considering the lactation period of 21 days (Medina et al., 1972), the highest percentage of juveniles appeared in the collection about two months after the peak of the breeding period. The smallest rat captured weighs only 24 grams which may be just about the size at weaning.

There are two peaks in the incidence of rats less than 80 grams in body weight (Table 9). These peaks confirms the existence of two main breeding seasons of rats in Siniloan. Both occurred about two months after the peaks of pregnancy has been attained. A marked increase in the number of small rats was noted in January following the peak in November. An increase in the proportion of juveniles in June and July substantiates the hypothesis of considerable breeding during the summer

Table 9. Monthly changes in the young - adult ratio of all rats collected for this study at Siniloan, Laguna.

Months	Total Rats	Number of young	Number of adults	Percent Young
August, 1971	25	4	21	16.00
September	78	12	66	15.38
October	51	10	41	19.60
November	148	15	133	10.13
December	194	31	163	15.98
January, 1972	62	25	37	40.32
February	21	6	18	28.57
March	14	2	12	14.28
April	76	14	62	18.42
May	71	27	54	38.07
June	108	54	63	50.00
July	84	40	53	47.62
Total	932	240	692	26.21

months of March and April. The low incidence of juveniles in March and November confirms my suspicion that there is little or no breeding activity during the months of January and August.

C. Sex Ratio

Small mammal trappers have often found a slight preponderance of males in their returns. Among the workers with the present species (Tigner, 1972; Sanchez et al., 1971; Swink et al., 1970; Alfonso and Castillo, 1970; Uhler, 1967; Sumangil and Aquino, 1958) and with *Rattus argentiventer* (Sumangil et al., 1963; Rosell, 1959; Harrison, 1951), Tigner and Alfonso were only those whose samples were large enough to demonstrate that sex ratio of trapped rats was statistically significant from a ratio of 50 percent males, in favor of the females.

A total of 760 rats were trapped from August, 1971 through July, 1972 consisting of 400 males and 360 females (Table 10). The over-all sex ratio of 51.83 percent was not statistically different from the ratio of 0.5 males. However, the monthly sex ratios indicated a variable pattern. There appears to be a high correlation ($r = 0.723$). The proportion of males in the sample increased appreciably during the height of the breeding season and tended to decrease during the non-breeding months (Figure 5). This may be attributed to the wider home ranges of the males than the females. Studies of Venezuelan roof rats by Gomez (1960) indicated that males were recaptured up to 80 meters from the point of release, while most females were recaptured from 15

Table 10. Monthly changes in the sex ratio of all rats trapped in Siniloan, Laguna, August, 1971 through July. 1972.

Months	Total rats	Number of males	Number of females	Sex a/ ratio	Chi-square
August, 1971	25	8	17	32.0	3.24
September	78	40	38	51.28	0.05
October	51	30	21	58.82	1.58
November	84	50	34	59.52	0.67
December	82	48	34	58.54	0.86
January, 1972	62	22	40	35.48	5.22
February	23	11	12	47.82	0.002
March	14	9	5	64.29	1.14
April	78	45	33	57.69	1.85
May	71	38	33	53.52	0.35
June	108	56	52	51.85	0.15
July	84	43	41	51.19	0.19
Total	760	400	360	51.83	2.10

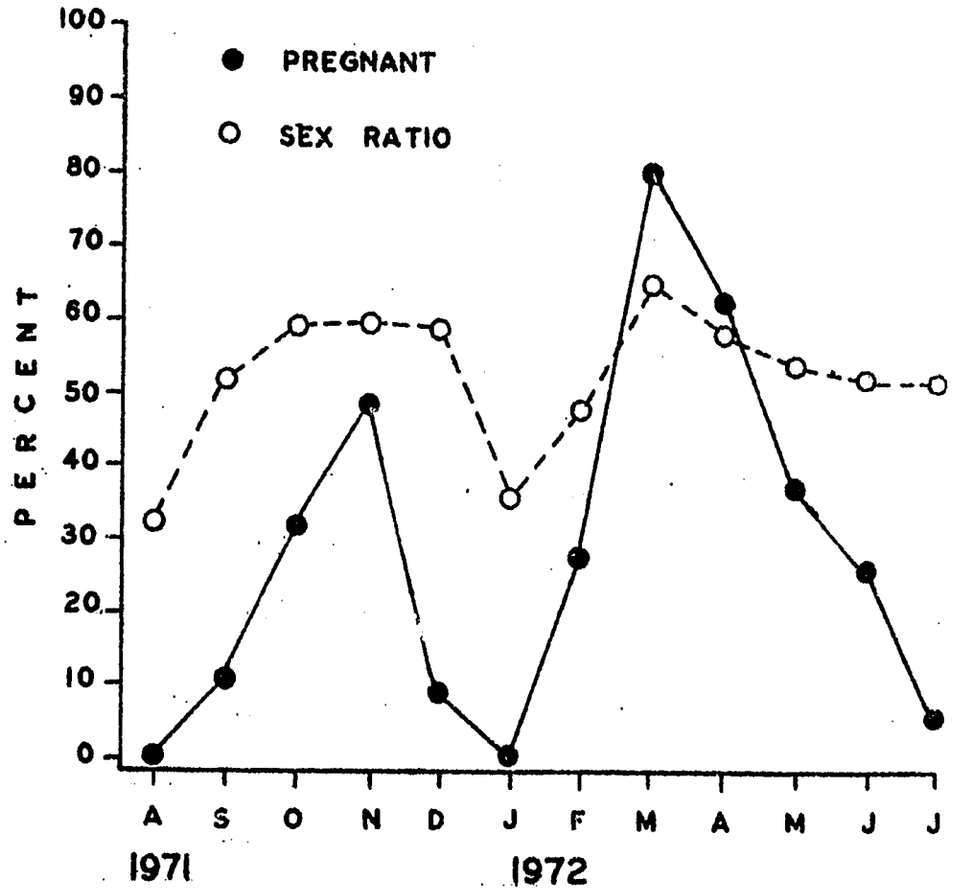

Figure 5. Graph showing relationship between breeding and monthly sex ratio.

to 20 meters from the original trap, but not much farther. Thus widely ranging males would come in contact with more traps and would be caught more often in relation to their absolute number than females. Parkes (1924a, as cited by Laurie (1946), however, found among laboratory-bred mice that the proportion of males was lowest in the height of the breeding season. This sexual difference in movement might also be induced by the care that females must give to their young in nests and burrows. Female rats in advanced stage of pregnancy become less and less mobile and their tendency to leave the nest is reduced correspondingly. Consequently, their chances to meet with a trap will be reduced correspondingly (Table 11).

The secondary sex ratio can be further altered by differential growth and mortality (Jackson, 1952). Analysis of the data by size group (Table 12) indicated that the males predominate in the youngest class, and females in the oldest class. The deviation from the 50

Table 11. Number of pregnant females captured in relation to stages of pregnancy.

Length of embryos (mm)	Assumed age (days)	Total females	Total embryos	Average per female
Less than 7 mm	6-11	58	593	10.22
7-18 mm	12-16	31	292	9.42
More than 19 mm	17-22	18	150	8.33
Total and averages		107	1035	9.67

Table 12. Sex ratio in various weight classes of *Rattus rattus mindanensis*.

Weight class (g)	Total rats	Number of males	Number of females	Per cent males
105	183	111	72	60.65
105-184	270	116	154	42.96
185-262	388	214	174	55.15
265	82	39	43	47.56
Total	923	480	443	52.40

percent ratio in the youngest class is suggested by Ecke (1955) to be due to the faster growth rate among males. Predominance of females in the oldest size groups suggests greater male mortality with age.

D. Rat Population Indices and Seasonal Fluctuations

Table 13 shows the monthly population indices of rats in the study area. There were only two species of rats caught in the rice field for the whole trapping period. All rats caught, except for four *Rattus exulans*, were *Rattus rattus mindanensis* comprising more than 99 percent of the total collection.

Using the trapline catches as an index of rat population, the population showed monthly fluctuations (Fig. 6). The rat population density seemed to increase with the advent of the rainy season

Table 13. Population density index of ricefield rats in Siniloan based on monthly trapline catches.

Month	Number of trapnights	Total rats caught	Trapping incidence (%)
August, 1971	110	25	22.72
September	473	78	16.49
October	295	51	17.28
November	590	84	14.23
December	960	82	8.54
January, 1972	638	62	9.72
February	258	23	8.91
March	376	14	3.72
April	717	78	10.88
May	546	71	13.00
June	600	108	18.00
July	290	83	28.62
Total	5853	748	12.95*

*Average percent trapping incidence per month.

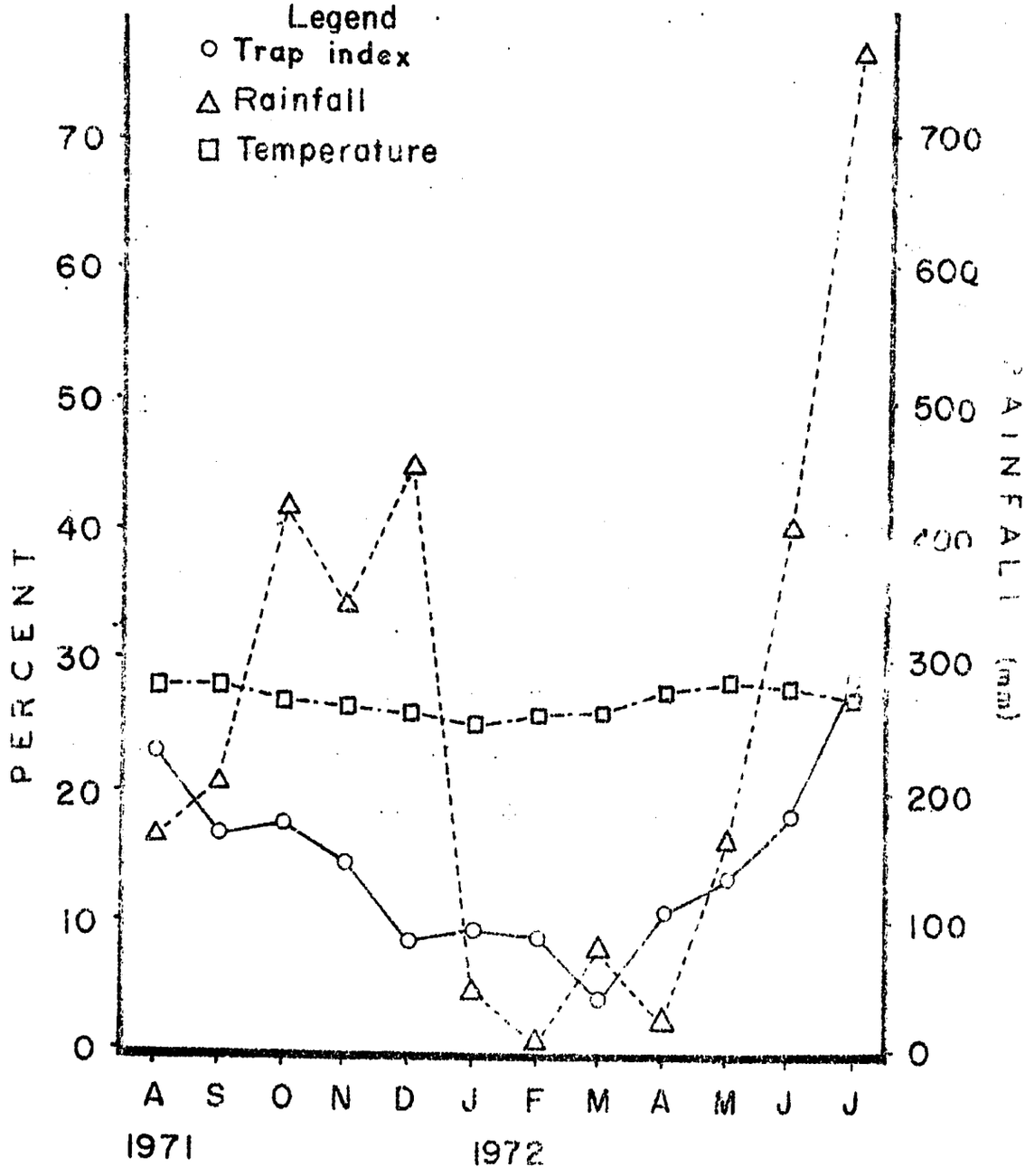

Figure 6. Monthly trapline catches of field rats in relation to rainfall and temperature.

reaching the peak in June, July and August. During the month of August when the field lie fallow, rats can subsist on ratooning rice, succulent grasses and insects. The lowest trapping incidence occurred in January, February and March, after the palagad crop has been harvested. This period corresponds to the dry months in Siniloan. Since rice is a preferred habitat its absence during these months apparently increased competition for food, cover, and other resources resulting in the dupletion of the rat population through increased movement or migration into the surrounding wastelands. A vigorous rat control campaign was also waged during the dry months and this may have aided in the abrupt reduction in the size of the rat population. In IRRI, however, Uhler (1967) observed that population peaks occurred from June to August and November to February. This marked dissimilarity in the population dynamics of one rat species in the different areas points to the role of environmental influence on rat populations.

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